Low-flow maturation failure of distal accesses: Treatment by angioplasty of forearm arteries

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Background: **Forearm artery lesions are a frequent cause of distal fistula maturation failure. Surgical treatment is difficult because of highly calcified arteries. To redo the arteriovenous anastomosis higher up the forearm is technically difficult and often ineffective because arteries cannot be enlarged. It also causes a loss in puncture zone. Creation of brachial accesses leads to a high risk of distal ischemia.**

Methods: **From September 2000 to September 2006, we performed percutaneous transluminal angioplasty (PTA) of forearm arteries in 25 patients with failing distal access maturation. We reported immediate results of the dilatation and retrospectively analyzed the outcome of the accesses after the procedure.**

Results: **Forearm artery PTA was achieved in all 25 patients. Three main complications occurred: severe spasms precluding precise assessment of the artery patency after dilatation, rupture easily treated by prolonged low-pressure balloon inflation, and early rethrombosis leading to access loss. Follow-up was available in 23 patients. PTA failed to restore a sufficient access flow in two patients (the access loss and an insufficient increase in flow). In the remaining 21 (91%), accesses started to be used for hemodialysis without difficulties. Primary patency access rates after PTA were 83% (range, 60%-93%) at 1 year and 74% (range, 47%-89%) at 2 years. Secondary access patency rates were 86% (range, 64%-95%) at 1 and 3 years.**

Conclusion: **When a distal access fails to mature because of forearm artery lesions, PTA should be done and will salvage the fistula without risk of distal ischemia and cardiac failure. Efficacy of PTA clearly influences surgical strategy and is a major argument in favor of attempting to create distal accesses in patients with mild distal artery lesions. Even in cases of failure, such as early occlusion of the fistula, this technique does not jeopardize further proximal access creation. Forearm access creation should be avoided only in cases of extremely severe distal artery lesions. (J Vasc Surg 2009;49:995-9.)**

After creation of an arteriovenous anastomosis, the large difference in pressure between the artery and the vein causes a large increase in flow. That increase in flow is responsible for fistula maturation, causing a progressive enlargement of arteries and veins and venous wall modifications such as thickening and a decreased tendency to spasm, so the vein becomes more resistant to venous punctures. Distal forearm artery lesions may restrict the increase in flow and prevent maturation of the distal access.

To surgically redo the arteriovenous anastomosis higher up at the forearm is technically difficult or unfeasible when the proximal part of the radial or ulnar artery is too diseased and highly calcified, and it is often ineffective because arteries cannot enlarge. Such an approach also leads to a large loss in puncture zone, and the creation of brachial accesses is associated with an increased risk of distal ischemia.

From September 2000 to September 2006, we attempted percutaneous transluminal angioplasty (PTA) of forearm arteries in 25 patients with failure of distally based access maturation. This article reports the immediate results and follow-up of this procedure.

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METHODS

Patients. Patients were 11 men and 14 women with a mean age 62 years (range, 31-85 years). Only two patients had been undergoing hemodialysis for >2 months at the time of access creation. At the time of PTA, 18 patients were receiving long-term hemodialysis and seven had yet to receive hemodialysis. In all patients, a wrist-based access had failed to mature. For this retrospective study, we consider as maturation failure fistulas created for >6 weeks that could not be used and were never regularly used for hemodialysis because of severe difficulties in puncture or inability to deliver a minimum dialysis flow of at least 300 mL/min for the total duration of dialysis.

The study included all patients in whom access development failure appeared due to forearm artery disease. Diagnosis of forearm arterial disease was by duplex Doppler imaging and confirmed by angiogram. We excluded all patients in whom the access failed to develop because of lesions located at the arteriovenous anastomosis or on the venous side of the access. Patients with difficulties in puncture due to deep accesses were also excluded.

Fistulas had been created 5.5 ± 4.8 months (range, 2-18 months) before the PTA. Patients with diabetes mellitus and distal arm arteriosclerosis had not been evaluated at the time of access creation because surgeons thought these pathologies would not prevent access development. In two patients the arteriovenous anastomosis had been

surgically redone, but that treatment failed to increase the flow sufficiently for access maturation. Fistulas had never been punctured in 18 patients. In the remaining seven patients, hemodialysis was unsatisfactory because the flow was too low and difficulties in puncture.

Accesses were 24 radiocephalic (21 left and 3 right) and one right ulnobasilic. Five patients complained of very mild distal ischemia limited to a cold hand and mild pain during dialysis. The forearm arterial lesions were related to diabetes in 18 patients and to a coronary arteriography by the radial artery route in one patient. In the six remaining patients, no cause was found except risk factors of atheroma and renal failure. A venous lesion >50% was associated with the arterial disease in five patients; in all of these the arterial lesions were more severe and explained failure of the access to mature.

Preoperative imaging. We report only the results color Doppler ultrasound (CDU) imaging done in 18 patients at our institution <10 days before the PTA. CDU imaging of the seven other patients was done in various institutions by various investigators using different equipment and techniques, and they did not measure access flow in all patients. The CDU manipulation and image optimization at our institution was done by a single investigator (G.F.) who used an ATL HDI 5000 scanner (Phillips Medical Systems, Bothell, Wash). The SonoCT feature and harmonic imaging were used in all cases. A 7- to 4-MHz linear probe was used to visualize the deepest arterial segments, and a 15-to 7-MHz probe was used for most distal and superficial arteries.

The CDU measurement of access flow rates was performed on the brachial artery. The diameter of the feeding artery chosen for flow calculation was determined by B-mode ultrasound imaging in a transverse plane from inner edge to inner edge and the accuracy of the measurement was controlled by TM mode. The cross-sectional area is automatically calculated. The time-averaged velocity (TAV) from Doppler spectra was obtained with a large sample volume size insonating the entire luminal vessel in a longitudinal plane, with an insonating angle maintained at ≤60°. TAV (cm/s) × cross-section area (cm^2) was classified as volume flow (mL/mm).

For CDU assessment of stenosis of the feeding artery, the vascular access is examined in the longitudinal and transverse planes from the brachial artery to the anastomosis. Direct characteristics at the area of narrowing are identified by B-mode ultrasound imaging. The degree of stenosis is usually determined by calculating reduction in the luminal diameter, which is easy if the wall vessel is not too calcified. Regardless, color flow imaging can identify the area of stenosis by using variance analysis, detection of blooming, and aliasing. For calculation of stenosis >50%, the peak systolic velocity (PSV) in the area of main color flow disturbance was recorded on spectral analysis and must be more than three times the peak systolic velocity of a nearby normal segment (PSV ratio >3).

Angioplasty technique. Lidocaine (1%) was used as a local anesthetic at the puncture site, and some patients were also given nitrogen monoxide. All angioplasties were attempted on outpatient basis. In patients already undergoing hemodialysis, an angiogram was obtained using 50% diluted iodine contrast material (iobitridol 350, Guerbet; or iohexol 350, Amersham Health) injected at the rate of 4 to 5 mL during 2 seconds. In patients not yet undergoing hemodialysis, contrast was diluted to 80% and injected for 1 second at the same rate. A total of <10 mL of contrast was usually sufficient for the entire procedure.

In 20 patients, preoperative CDU clearly identified feeding artery lesions (even when flow was not measured) as the cause of maturation failure; thus, an antegrade brachial artery route was used for PTA. To minimize risks of brachial hematoma, the procedure was performed through a 4F sheath (Fig 1).

In the five remaining patients, ultrasound imaging was not sufficient to determine that forearm artery lesions were amenable to PTA. Angiography in these patients done by a retrograde brachial artery puncture through a 20-gauge angiography catheter confirmed that PTA could be attempted; then dilatation was performed by retrograde radial artery catheterization using a 5F or 6F sheath. The sheath chosen was larger than for the brachial arterial route because catheterization of the artery through the anastomosis might have required use of 0.035-inch guidewire and 5F balloon catheter and because hematoma was far less feared.

After injection of 2000 IU of heparin, lesions of the forearm artery directly feeding the fistula were crossed with a 0.014-inch guidewire (BMW or Spartacore, Abbott) then a balloon angioplasty catheter (Viva and Sterling, Boston Scientific; Savvy, Cordis; Fox SV, Abbott Vascular) was advanced over the wire, placed across the stenosis, then inflated at the pressure required to obtain the disappearance of any waist on the balloon. Inflations were maintained for at least 30 seconds and repeated at least once.

The length of the segment dilated was ≥10 cm in 11 patients (10 patients with diabetes and the patient with lesions after coronary arteriography), the disease involving the entire artery upstream to the inflow. The mean size of the balloon used was 3.9 ± 0.48 mm (range, 3.5-5 mm). We learned from our experience that balloons ≥3.5 mm should be used to obtain satisfactory results in forearm artery dilatation. Balloon length was 2 to 10 cm and was determined according to the length of the lesions.

Statistical analysis. Success rates, patency rates, and complications were defined in agreement with the guidelines and reporting standards of the American Society of Cardiovascular and Interventional Radiology.[1] We considered as a morphologic success all the procedures ending with a clear increase in diameter of the artery supplying the access all along its length. The procedure was considered a functional success when an access could be punctured easily and provided dialysis flow of ≥300 mL/min without recirculation. Accesses were considered patent when they were used for hemodialysis without any dysfunction. Primary and secondary patency of the access started on the day of the dilatation. We considered as primary patency all

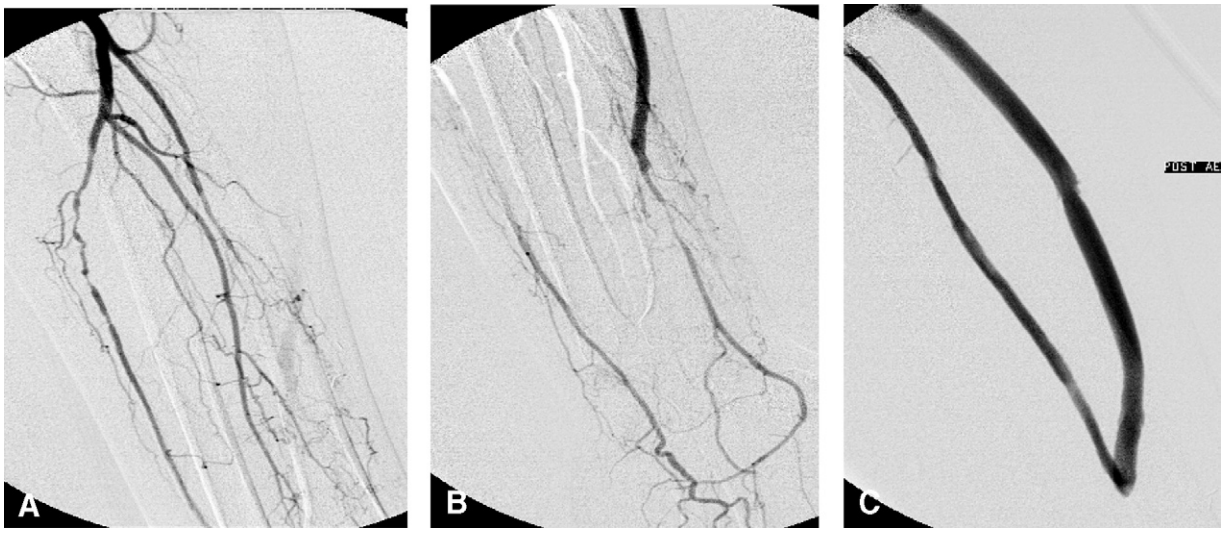

Fig 1. A, Angiography shows a stenosed ulnar artery, an almost occluded radial artery, and late opacification of cephalic vein. **B,** Opacification of palmars arches. **C,** Antegrade brachial percutaneous transluminal angioplasty using a 4F sheath, 0.014-inch guidewire, and 4-mm × 40-mm balloon, resulted in optimal dilatation of radial artery and good flow in the cephalic vein.

accesses with satisfactory dialysis without any dysfunction and without any surgical or endovascular intervention.

End of follow-up occurred when a patient died or underwent kidney transplantation with an angioaccess still functioning. Follow-up was done at the referring institution, so no precise protocol was applied in patient follow-up. The data were recorded by the nephrologists who were in charge of the patient and particularly by the nephrologist at referring institution.

Quantitative values are reported as means ± one standard deviation (SD) or medians and interquartile range (IQR), as appropriate. Probabilities and median times of survival are reported with the 95% confidence interval (CI). Survival was analyzed as the number of months from the PTA of the forearm arteries to patient's death or the last follow-up visit. Survival probabilities were estimated using the Kaplan-Meier method. All statistical analyses were done using SAS 8.2 (SAS Inst, Cary, NC) and Prism 4 (GraphPad, San Diego, Calif) software.

RESULTS

Brachial artery access flow, measured <10 days before the PTA in 18 patients, was 315 ± 122 mL/min. Lesions of forearm arteries demonstrated by pretreatment angiography were often very diffuse, involving palmar arches, ulnar arteries, and the distal segment of the radial arteries. Indeed, these arteries appeared normal on the pretreatment angiogram in only two patients and were severely stenosed or occluded in 21. In the last two patients, they were not studied.

Immediate morphologic results of the dilatation of the forearm artery directly feeding the fistula were satisfactory in all 25 patients except in one where spasm precluded precise assessment of the radial artery patency. In that patient, access flow was 360 mL/min before PTA and 600 ml/min after PTA, with angiography showing that the dilated radial artery was satisfactorily patent. Major spasm also occurred during an associated PTA of an ulnar artery in this patient. Seven other lesions, not located in the artery directly supplying the fistula, were treated at the same time by PTA. Five were located on the access itself and two on the ulnar artery. One of those two latter patients complained of mild distal ischemia. All of these angioplasties were also successful.

Few complications occurred. One radial artery occluded just after the procedure and was treated by manual aspiration thrombectomy and repeat angioplasty. That access definitively occluded a few weeks later and was lost. Two ruptures occurred during ulnar artery angioplasty; both were easily treated by repeat 3-minute balloon inflations at low pressure. Start of hemodialysis was never hastened after the procedure, despite injection of contrast material.

One patient died 6 weeks after angioplasty, before hemodialysis started, and a second patient was lost to follow-up. Follow-up is available for the remaining 23 patients (92%). The access thrombosed during the month after the procedure in the patient with radial artery stenting. The increase in flow was insufficient in another fistula that was never used; from 150 mL/min before PTA it rose to 400 mL/min after PTA for 1 and 2 months. In the remaining 21 patients (91%), the fistula could be used.

During the follow-up, two radial artery restenoses occurred, the first at 22 months and the second at 33 months. Both were successfully treated by PTA (plus stenting for the first one), and both accesses were still functioning normally

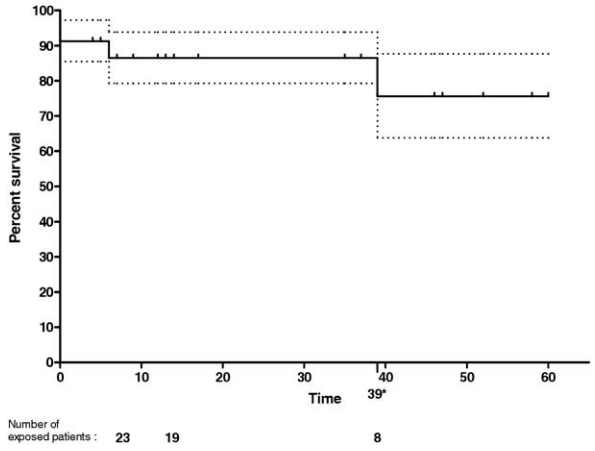

Fig 2. Secondary patency of the access *(solid line)* is presented with the interquartile range *(dashed line)*. In the horizontal axis, the survival time in months followed by a star symbol indicates the point until the standard error exceeds 10%.

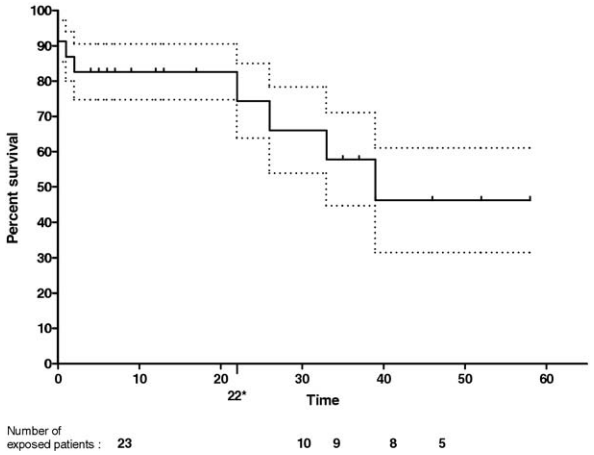

Fig 3. Primacy patency of the access *(solid line)* is shown with the interquartile range *(dashed line)* In the horizontal axis, the survival time in months followed by a star symbol indicates the point until the standard error exceeds 10%.

at 52 and 47 months. The venous stenosis did not recur in four of five venous lesions dilated at the time of the PTA of the forearm arteries with a 5-, 39-, 39-, and 46-month follow-up. The fifth stenosis was dilated once again after 2 months; that access was still functioning normally when the patient died at month 14. Four PTAs were also done on the venous side of the access at 2, 4, 26 and 33 months, three times for a new stenosis and once for a restenosis.

Six patients died during follow-up. Four had diabetes and died at 9, 9, 35, and 37 months. The other two died at 13 and 14 months. Probabilities and median times of survival were 14 months (95% CI, 7-39; IQR, 6-46 months). An additional patient with diabetes received a renal transplant at 47 months.

Two accesses failed, one at 6 months, mostly because of restenosis of a lesion on a vein of poor quality, and the second, which had been functioning normally, thrombosed at 39 months. Thus, after forearm artery PTA accesses, primary patency (Fig 2) was 83% (IQR, 60%-93%) at 1 year and 74% (IQR, 47%-89%) at 2 years. The secondary patency access rate (Fig 3) was 86% (IQR, 64%-95%) at 1 and 3 years.

DISCUSSION

Creation of a vascular access for hemodialysis in patients who have diabetes and those with distal artery lesions is a challenge and is still controversial. Traditionally, distal access is the first choice[2,3]; however, such accesses may thrombose or above all never mature because of low flow.[4-6] Up to 30.5% of radiocephalic access dysfunction is due to radial artery stenoses.[7] Despite that high prevalence, very little has been published about PTA of arteries feeding distally based fistulas. A few articles have reported some cases of PTA of proximal arteries[8] and of forearm arteries[9,10] for treatment of distal ischemia. However, we found only one article about treatment of low-flow access by inflow artery PTA.[10] Falk[11] reported nine cases of inflow artery angioplasty for nonmaturing fistulas but did not specify whether the PTA was of forearm or of more proximal arteries, except for one, a radial artery dilatation complicated of rupture. The only two other reported cases of radial artery PTA for nonmaturating access are by Turmel-Rodrigues et al[12] and Song et al,[13] who performed PTA at the same time for radial artery and venous stenosis in failing accesses. Arterial rupture is certainly a complication to fear after such an approach. It is usually easily treated by low-pressure prolonged inflations. Regardless, it may lead to aneurysm occurrence and even to access loss, as happened in one of our patients and in the patient reported by Falk.[11]

When the fistula does not mature because of lesions located at the anastomosis or close to it, surgically redoing the anastomosis is a well-established treatment even though there are limited data and still some controversies[14] with this approach. When the fistula does not mature because of lesions located upstream to the access anastomotic site, our series clearly shows that PTA is a simple, easy, and safe treatment that can be performed on an outpatient basis. Indeed, among our 23 patients with available follow-up, PTA restored a sufficient access flow to allow satisfactory hemodialysis in 21 (91%). This approach preserves many accesses that would have been lost in patients for whom creation of another access likely would have been challenging.

In patients who have diabetes and in those with forearm arteriosclerosis, some favor brachial-based accesses[4,5] because of the high rate of maturation. Brachial accesses are far from ideal in such patients compared with distal accesses, however. They are associated with a higher risk of distal ischemia,[2,5-8-15] they cause more cardiac failure because of their higher flow, especially in patients with decreased cardiac reserve[3]; they lead to a large decrease in venous pool because the entire cephalic and basilic vein in the forearm are lost, and they require more secondary procedures to maintain patency.[5]

Primary patency of distal accesses that failed to develop was much better after PTA of forearm arteries, 83% (IQR, 60%-93%) at 1 year and 74% (IQR, 47%-89%) at 2 years, than reported primary access patency after PTA of access venous lesions of 28% at 1 year for Song et al[13] and 39% for Turmel-Rodrigues, et al.[12] Although forearm arteries have a small diameter, the lesions are often long. Most of our patients had diabetes mellitus, the restenosis rate was low, and stenting appeared unnecessary. The high flow due to the access possibly decreased the risk of early thrombosis and favored artery remodeling.

In our series, occurrence of venous lesion (4 events at 2, 4, 26, and 33months) had greater influence on primary patency than arterial restenosis (2 late events 22 and 33 months). Secondary patency of distal accesses after forearm artery PTA of 86% (IQR, 64%-95%) at 1 and 3 years is also comparable with secondary patency of distal access maturating normally in nondiabetic patients. The accesses flow in our patients was just sufficient for adequate flow for hemodialysis and to prevent acute thrombosis; however, accesses flow was never high, so that turbulence and endoluminal pressure was likely moderate, which may also have limited restenosis. Five patients in our series complained of very mild distal ischemia. One of the 2 associated ulnar artery dilatations was performed in order to improve hand supply. No patient with ischemia deteriorated after PTA, and symptoms disappeared in all of them, confirming findings in the literature[9,10] showing that PTA of forearm arteries may improve hand supply and symptoms in cases of distal ischemia. Ligation of distal radial artery distal to the inflow is the usual treatment of such distal ischemia,[9,16] but it was never indicated and performed in the series reported here.

CONCLUSIONS

Many patients with diabetes have forearm arteries that are of satisfactory quality. In those patients, a distally based access will develop quickly and can be used a few weeks after creation. In others, despite distal artery lesions, accesses will have sufficient flow, will develop within reasonable time, and then will be used for a long time for hemodialysis. An access that fails to mature usually remains open,[4] and PTA should then be performed to salvage the fistula without risk of distal ischemia and of cardiac failure. The efficacy of PTA of forearm arteries clearly influences surgical strategy and is a major argument in favor of attempting to create distal accesses in such patients. Furthermore, even a failure, such as early occlusion of the fistula after PTA, does not jeopardize further proximal access creation.

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AUTHOR CONTRIBUTIONS

Analysis and interpretation: AR, LN
Data collection: AR, LN, BB
Writing the article: AR, LN
Critical revision of the article: JS, PB, BB, GF
Final approval of the article: AR, LN, BB, JS, PB, GF
Statistical analysis: AR, LN
Obtained funding: Not applicable
Overall responsibility: AR

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